Dispersion of longitudinal momentum distributions in fragmentation reactions*

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In the last decade, a series of experiments devoted to systematically study fragmentation reactions were carried out at the FRagment Separator (FRS), GSI. The residual nuclei formed in the fragmentation of several relativistic primary beams were separated in-flight and identified before they decayed. The whole isotopic distribution was obtained for every element, and once the nuclides were identified their velocities could be evaluated precisely from their magnetic rigidities. This method yielded absolute and extremely accurate velocity values (resolution ~$5\cdot 10^{-4}$), whose knowledge also permitted to disentangle fission and binary-decay events from fragmentation and multifragmentation events.

In this work we profit from the detailed overview on the velocity spectra of residual nuclei measured in several fragmentation reactions to revisit our understanding on the standard deviation ($\sigma_{P||}$) of the longitudinal momentum distribution of the final fragments of mass A_f. Please note that this work refers to fragmentation products only (fission and binary-decay products were discharged). Previous works on this topic date back to the theoretical work of Goldhaber (1974) [1] who calculated the influence of the abrasion stage, and to the empirical prescription of Morrissey (1989) [2], limited to rather peripheral collisions. We extended our study to light residual nuclei produced in mid-peripheral collisions. In this context, beside the contribution of abrasion, we considered additionally the effects on the width of the momentum distribution due to thermal break-up and the following sequential evaporation. The aim of the work was to determine a simple analytical formula which could satisfactorily describe $\sigma_{P||}$; this aim sometimes implied some simplifying assumptions in the description of the different processes.

In the abrasion process, we considered the nucleons as a Fermi gas and we assumed that each abraded nucleon contributed to the momentum of the fragment by its Fermi momentum, according to the idea of Golhaber [1].

During the sequential evaporation, each emitted particle introduces a recoil momentum to the corresponding compound nucleus. Since evaporation is an isotropic process, it will not change the mean velocity of the fragment; however it will increase the width of the distribution. The overall contribution from the recoil of evaporated particles to $\sigma_{P||}$ was calculated summing up all the individual contributions, assuming an average value of the mean momentum of the emitted particle.

According to what reported in ref. [3], in an approximate way one can establish if a certain final fragment underwent a break-up process. For these multifragmentation products, after abrasion, an additional sudden reduction of mass occurs. The corresponding change in momentum can be calculated in the frame of the Fermi gas model, providing that the Fermi momentum is reduced due to the increase of volume due to the thermal expansion and due to the thermal motion of the nucleons, according to ref. [4]. Finally, the Coulomb expansion of the emitting source at freeze-out is calculated as in ref. [5].

The results of the analytical formula are shown in figure 1 for three cases.

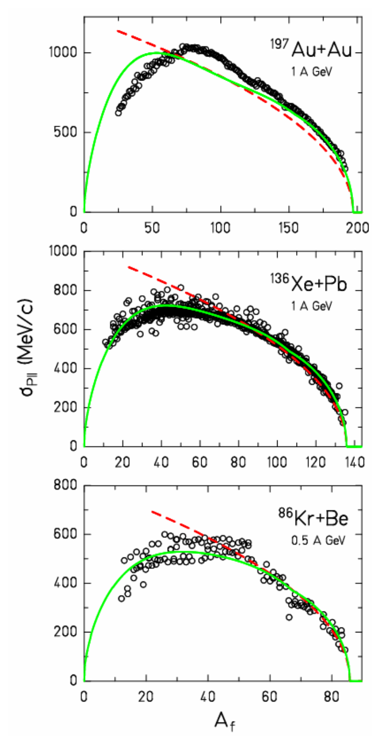

Figure 1: Standard deviation ($\sigma_{P||}$) of the longitudinal momentum distribution of the final fragments of mass A_f for three reactions: 1 *A* GeV ^{197}Au on Au [6], 1 *A* GeV ^{136}Xe on Pb [7], 0.5 *A* GeV ^{86}Kr on Be [8]. The dots are experimental data. The lines give the predictions of Morrissey's formula [8] (dashed) and of the analytical formula determined in this work (solid).

References

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